MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

ETM 7176 – OPTICAL COMMUNICATION SYSTEMS

M.Eng. (Telecommunication)

26 SEPTEMBER 2015
2.30 p.m – 5.30 p.m
(3 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **8** pages including cover page with **4** Questions only.

2. Attempt **ALL** questions. Each question carries different marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided. Please number your answers clearly.

Question 1

(a) Explain the terms

i. Critical Angle

[2 marks]

ii. Acceptance Angle

[2 marks]

(b) An optical fiber with a radius of $3\mu m$ and a refractive-index of the core and cladding being 1.46 and 1.457 respectively. If the fiber is illuminated by a ray of $1.3\mu m$ light, determine:

i. the normalised frequency (V)

[2 marks]

ii. the numerical aperture (NA)

[2 marks]

(c) A step index fiber with a core refractive index of 1.5 has a relative index difference of 1.3% and a core diameter of $50\mu m$.

i. Estimate the number of guided modes propagating in the fiber when the transmitted light has a wavelength of $1.55\mu m$

[3 marks]

ii. Determine the cut-off wavelength for single mode transmission in the fiber

[4 marks]

Continued...

(d) Considering a PIN photodiode, describe briefly the following:

i. Shot Noise

[2 marks]

ii. Thermal Noise

[2 marks]

iii. Explain how Shot noise and Thermal noise will impact the optical communication system performance in terms of Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER)

[6 marks]

Continued...

Question 2

You are an optical communications engineer at a consulting company. You have been assigned to prepare a proposal for a client on a suitable system design to be employed for an optical link between two floors in the same building 300 m apart. The requirements are summarized as follows:

Table Q2.1 Requirements

Bit-rate	2.5 Gb/s
Length	300 m
Minimum receiver power	-25 dBm
Modulation format	RZ

You may consider the following optical sources and fiber choices (Table Q2.2 and Q2.3) in your design.

Table Q2.2 Optical Source

	LED	**LED**	**DFB Laser**	**DFB Laser**
Wavelength (nm)	1300	850	1300	850
Maximum Power (dBm)	-20	-20	-3	-3
Spectral width (nm)	30	30	0.1	0.1
Transmitter rise-time (ns)	5	5	0.05	0.05

Continued...

Table Q2.3 Optical Fiber

	Single Mode Fiber	**Multimode Fiber**
Attenuation at 1300 nm (dB/ km)	0.8	0.9
Attenuation at 850 nm (dB/km)	3	3
Intermodal Dispersion Coefficient (ps/m)	0	10
Dispersion Coefficient at 1300 nm (ps/km.nm)	0	0
Dispersion Coefficient at 850 nm (ps/km.nm)	- 8.5	-8.5

(a) Based on the information provided in tables Q2.2 and Q2.3, propose a suitable optical source and fiber combination based on the requirements mentioned in table Q2.1 above.
[16 marks]

(b) Explain why your proposal is considered suitable.
[4 marks]

(Hint: You may need to consider maximum bandwidth due to dispersion and actual received power in your proposal)

(c) Suggest and elaborate, with the aid of a suitable diagram, a suitable solution to reduce the effect of intermodal dispersion in step-index multimode fiber.
[5 marks]

Continued...

Question 3

(a) You have been given ten 3-dB fibre couplers and eight Fabry-Perot filters. Design a 8-channel demultiplexer for a wavelength-division multiplexed (WDM) system, using as few couplers as possible. Explain briefly the working principle and label your design schematic properly.

[5 marks]

(b) (i) Justify the adoption of Optical Code-Division Multiple Access (OCDMA) in optical communication systems.

[3 marks]

(ii) Describe concisely the optical encoding process of Frequency-Encoded (FE-OCDMA) in coherent OCDMA scheme. Additionally, illustrate the corresponding temporal and spectral responses of the systems.

[6 marks]

(iii) Design an encoder for Direct Sequence (DS) OCDMA, using an optical splitter, fibre delay lines, and optical combiner for a code sequence of 1000111.

[5 marks]

(c) Prove the 3-dB advantage of homodyne detection by showing that the average electrical power generated by a coherent receiver is twice as large for homodyne detection as for heterodyne detection under identical operating conditions.

[6 marks]

Continued...

Question 4

(a) The parameter N is defined as $N^2 = \gamma P_0 L_D$, where γ is the nonlinear parameter, P_0 is the peak power of the pulse, and L_D is the dispersion length. Even though the fundamental soliton requires a specific shape and a certain peak power corresponding to $N = 1$, it can be created even when the pulse shape and the peak power deviate from the ideal conditions. Sketch and describe briefly the evolution of a "sech" input pulse with $N = 1.2$.

[4 marks]

(b) Consider a WDM system that utilises two soliton channels at wavelength λ_1 and λ_2. Since different wavelength travel at slightly different velocities in a fibre, the solitons of the faster channel will gradually overtake and pass through the slower channel solitons.

(i) What is the collision length for FWHM pulse width $T_s = 16$ ps, dispersion parameter, $D = 0.5$ ps/(nm.km) and $\Delta\lambda = \lambda_1 - \lambda_2 = 0.8$ nm ?

[3 marks]

(ii) Four-wave-mixing effects arise between the soliton pulses during their collision, but then collapse to zero afterwards. What is the upper bound for the amplifier spacing, L_{amp} to avoid amplifying these effects?

[3 marks]

(c) A 10 Gb/s soliton lightwave system is designed with a normalized soliton spacing, $2q_0 = 10$ to ensure well-separated solitons in the RZ bit stream. Evaluate the soliton width parameter T_0, FWHM pulse width T_s, peak power P_0, and pulse energy E_0 of the RZ signal, assuming the second-order dispersion coefficient $\beta_2 = -1$ ps^2/km, and the nonlinear parameter $\gamma = -2$ W^{-1}/km for the dispersion-shifted fibre.

[8 marks]

(d) With the aid of a suitable diagram, explain how atmosphere may distort the optical waveshape during propagation in the atmospheric optical channel.

[7 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper